

A Value Based Outlook on the Future of the Rio de Flag

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Abstract

The Rio de Flag is an ephemeral stream that flows throughout the City of Flagstaff in response to flood events and reclaimed water discharge. The Rio provides many different benefits to the city, in recreational value, community value, and environmental value. Benefits of the Rio de Flag were evaluated in order to inform future planning within the City of Flagstaff. Flagstaff's population continues to grow, and the City is concerned with shrinking aquifers and providing water security to residents for the future. With proposed infrastructure changes to increase discharge of reclaimed water into the system, the river morphology and recharge potential needed to be assessed. Environmental value was evaluated by mapping a portion of the Rio de Flag, from the water treatment plant off Babbitt Drive to Frances Short Pond near downtown Flagstaff. GIS data was then compiled to provide a map outlining erosion areas and soil recharge properties that can be seen along this reach of the Rio. High incision and potential soil recharge provide insight to stabilizing stream banks and the efficiency of aquifer recharge with an increased flow of reclaimed water. In collaboration with Friends of the Rio and Paul Beier, six game cameras were installed along this reach to provide insight to trail usage and recreational value. Visitors were counted and categorized based on use type such as: bikers, dog walkers, families, joggers, and others. A community survey was also distributed electronically throughout the city to determine the effect on quality of life that the Rio de Flag provides to citizens. The data provided from the camera and surveys provides insight into the perceived value along the Rio de Flag and Flagstaff Urban Trail System (FUTS), in recreational uses and intrinsic value. Data found that users appreciate a flow of water within the channel and feel the FUTS along the Rio positively affects their quality of life. These results can be used for the City

of Flagstaff to justify an increase in discharge of reclaimed water into the Rio de Flag in order to provide water security. Data also highlights the need for erosion control along reaches that visitors and locals find valuable in recreational or transportation uses.

Goal

Create a better understanding of the benefits of the Rio as well as inform future planning of reclaimed water use in the City of Flagstaff.

Background and Introduction

The Rio de Flag has a long history in the City of Flagstaff. It was originally diverted in the 1800s in order to avoid flooding in the town as people traveled and settled. Unfortunately, as the town continued to grow, residencies were built on top of floodplains and within major zones of natural disaster. Due to its location however, the Flagstaff Urban Trail System (FUTS) was somewhat built along the Rio de Flag path and has provided many useful benefits to the city. Flooding of the Rio de Flag and trails within the FUTS is only one major issue. Another more relevant issue in present day and for the future is addressing water security for the City of Flagstaff. With the population growing quickly, water demand is predicted to outpace water supply. The Rio de Flag flows in response to snowmelt, flood events, and more importantly, discharge of reclaimed water. There have been many investigations into the usages of reclaimed water in urban areas throughout the world. Reclaimed water could prove as a potential solution to water shortage in the United States; these data are specifically concerned with the efficiency of aquifer recharge within the Rio de Flag from discharge of reclaimed water. Within Flagstaff, the city council has proposed many ideas relating to water security, one of which is to divert treated reclaimed water from Wildcat Wastewater Plant into the river by infrastructure changes. This is an attempt to have that water infiltrate back into the aquifer within city limits. The Rio de Flag and the FUTS provide an extensive range of aesthetic, communal, and environmental benefits to the City of Flagstaff. Due to this proposal, this research investigates the current perceived community, recreational, and environmental values of the Rio de Flag and what benefits it offers the community in regards to planning for future flood control and water security.

Methods

Environmental Value

- GIS data mapped on foot to observe heavily incised areas
- Soil data downloaded from Web Soil Survey and added to GIS map as a shapefile
- Soil geologic properties evaluated to determine recharge potential

Recreational Value

- Six game cameras were placed along the Flagstaff Urban Trail System (FUTS) within the study area. Cameras were placed inconspicuously in order to avoid tampering or skewed data
- Cameras were placed in mid-October and left up for two weeks
- After two weeks, cameras were taken down and photographs were manually reviewed
- FUTS users were categorized by type of use and organized by time of day as well as day of the week (i.e. weekday or weekend)
- Data was compiled into a spreadsheet and used to create charts for interpretation

Community Value

- Survey of 10 questions varying multiple choice, select all that apply, and short answer questions
- Google docs survey distributed via Facebook, Friends of the Rio, and NAU SES list-serv
- Compiled graphs and charts for better usefulness

Value Objectives

Environmental Value

Use soil data to provide insight into the efficiency of aquifer recharge if discharge of reclaimed water into the Rio de Flag through town were increased. Incision data also provides guidelines for erosion and flood control. This data focuses an effort to improve bank stability in locations of which trails are frequently flooded or washed out.

Recreational Value

Understand trail use of the FUTS and the type of recreational value it provides to the City of Flagstaff. Additionally, evaluate the purpose of specific areas based on the most common use seen in a particular stretch.

Community Value

Provide community response data on intrinsic value to the City of Flagstaff to plan and fund for future flood control, trail building, and recharge projects within the Rio de Flag watershed.

Results

Environmental Results

Web Soil Survey Data:

Bedrock material	Natural Drainage	Available Water Storage	Depth to Water Table	Ksat	Ksat average in/hr	Recharge Potential	Percent Sand	Percent Clay
mixed alluvium	well drained	high	More than 80 inches	mod low to mod high	0.2	poor	28.5	41.7
weathered basalt	well drained	low	More than 80 inches	very low to mod low	0.12	poor	24.6	45.5
weathered basalt	well drained	low	More than 80 inches	very low to mod low	0.12	poor	24.6	45.5
mixed alluvium	well drained	high	More than 80 inches	mod high to high	1.28	excellent	37.4	20
mixed alluvium	well drained	medium	More than 80 inches	mod high to high	1.28	excellent	37.4	23
weathered limestone/sandstone	well drained	very low	More than 80 inches	very low to mod low	0.26	medium	32.8	40
weathered limestone/mixed alluvium	well drained	very low	More than 80 inches	mod low to mod high	0.87	excellent	44.3	15

Web Soil Survey data and soil properties downloaded along with a GIS shapefile (Nracs. Web Soil Survey, websoilsurvey.sc.egov.usda.gov).

Environmental Results Continued

GIS Data:

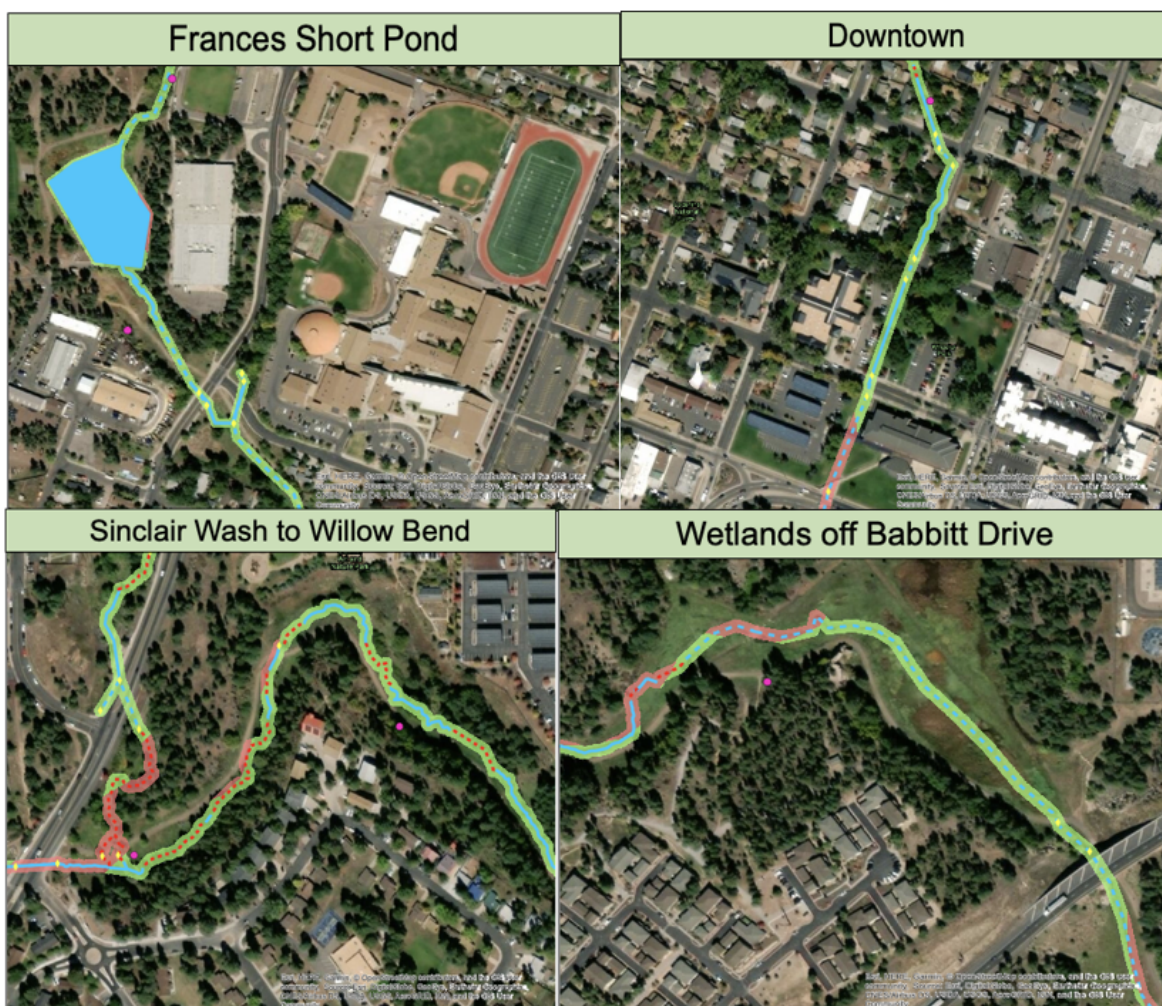
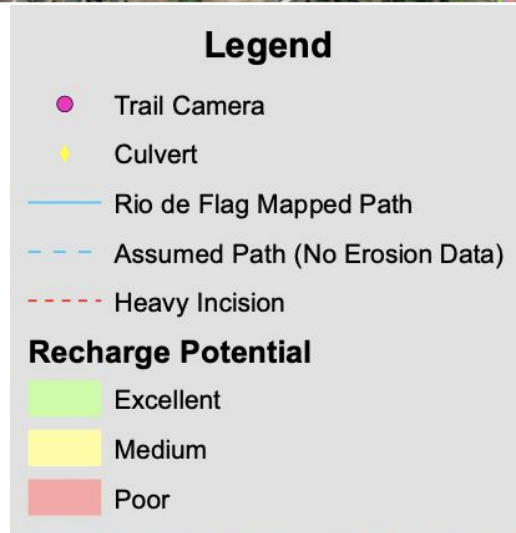


Figure 1: Soil data and Rio path were inputted into GIS as a shapefile. A buffer of 10 ft was created along the Rio de Flag with the soil shapefile.



USGS Soil Seepage Evaluation:

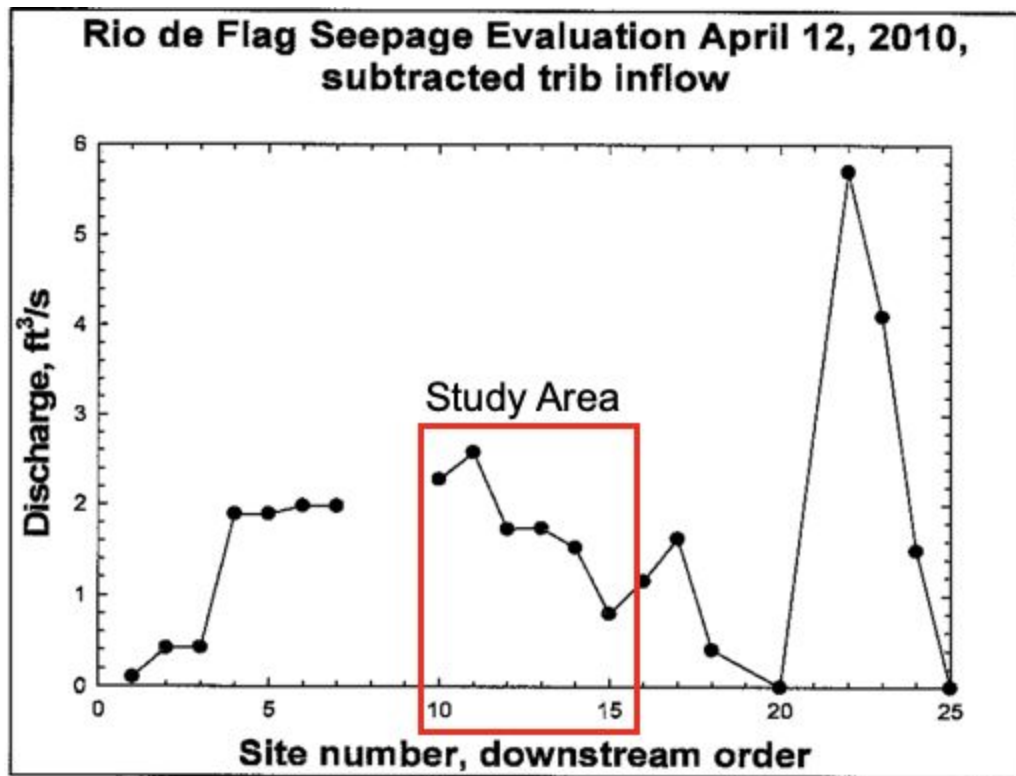


Figure 2: A seepage evaluation from the USGS. Areas 10-15 in the seepage study overlap with the study area in this research. Significant losses were observed in this area (Bills, Donald).

City Proposed Plan:

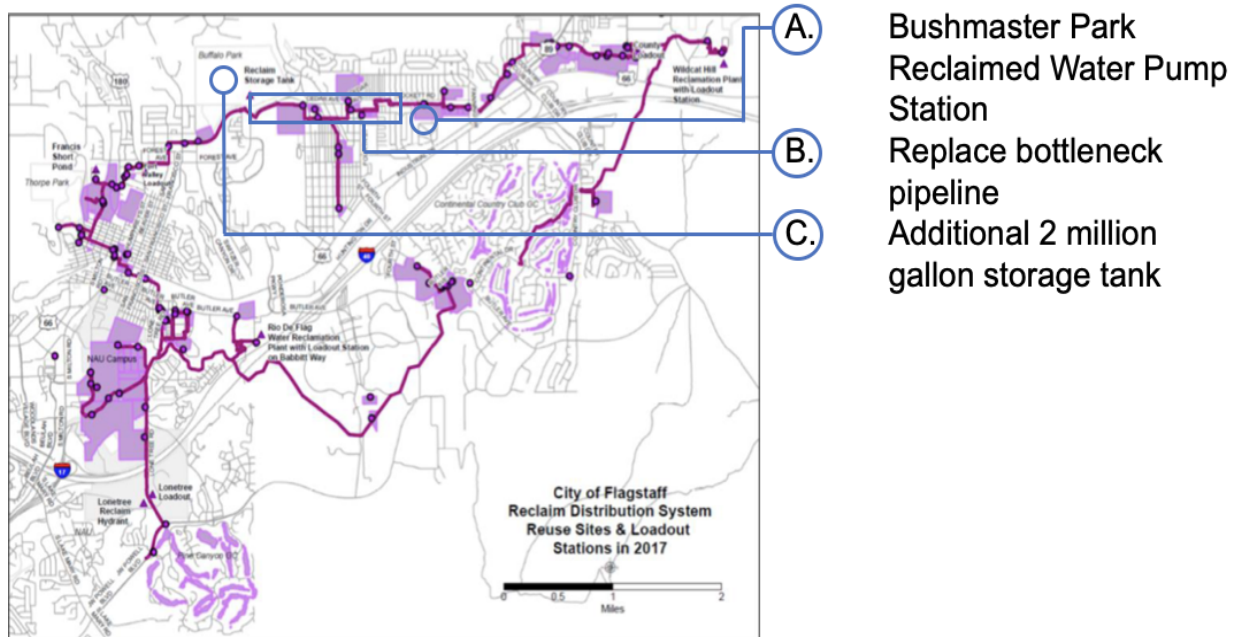


Figure 3: Proposed infrastructure changes from the City of Flagstaff. Map is the purple pipeline map, a map of reclaimed water pipelines through town.

Recreational Results

Frances Short Pond

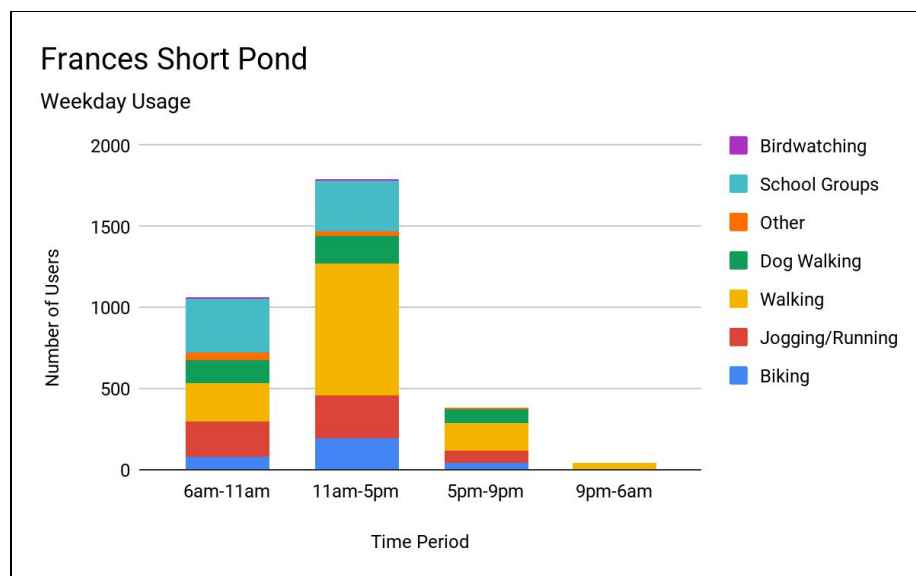


Figure 4: Weekday trail usage from two cameras placed on north and south sides of Frances Short Pond.

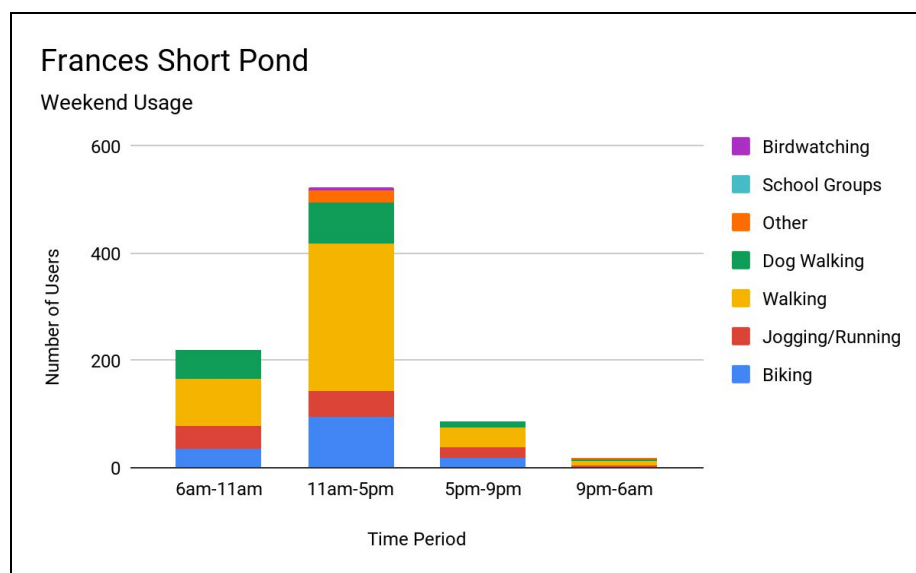


Figure 5: Weekend trail usage from two cameras placed on the north and south sides of Frances Short Pond.

Downtown

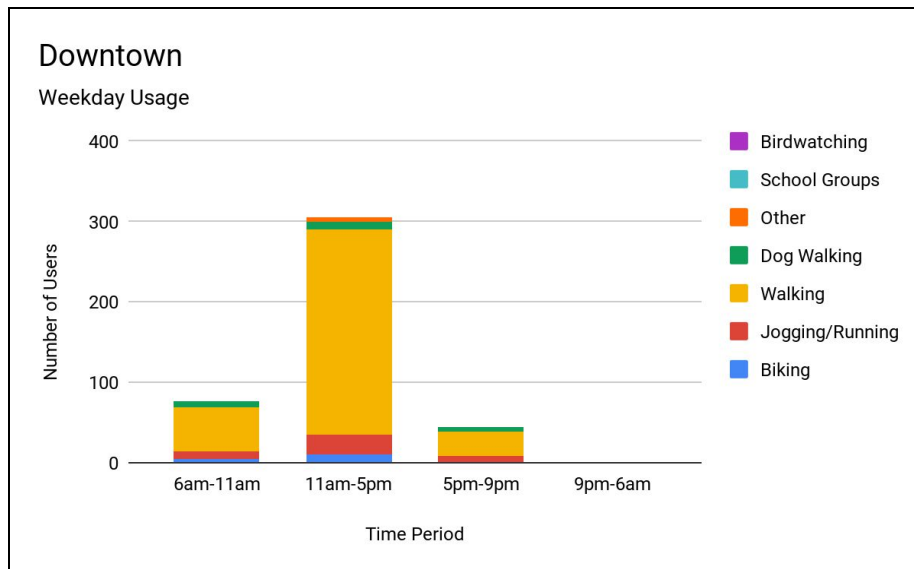


Figure 6: Weekday trail usage from one camera placed on the Karen Cooper passage of the FUTS north of the main library.

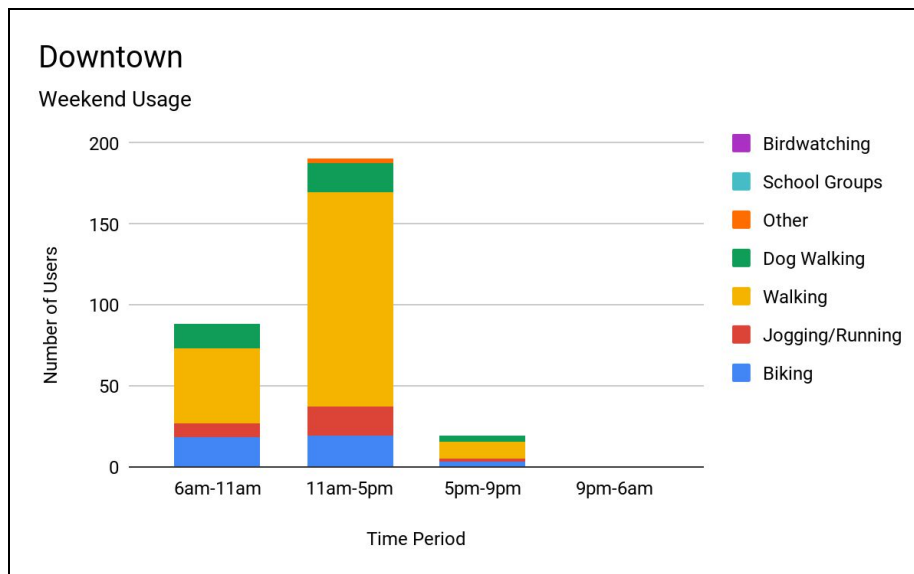


Figure 7: Weekend trail usage from one camera placed on the Karen Cooper passage of the FUTS north of the main library.

Sinclair Wash/ Willow Bend

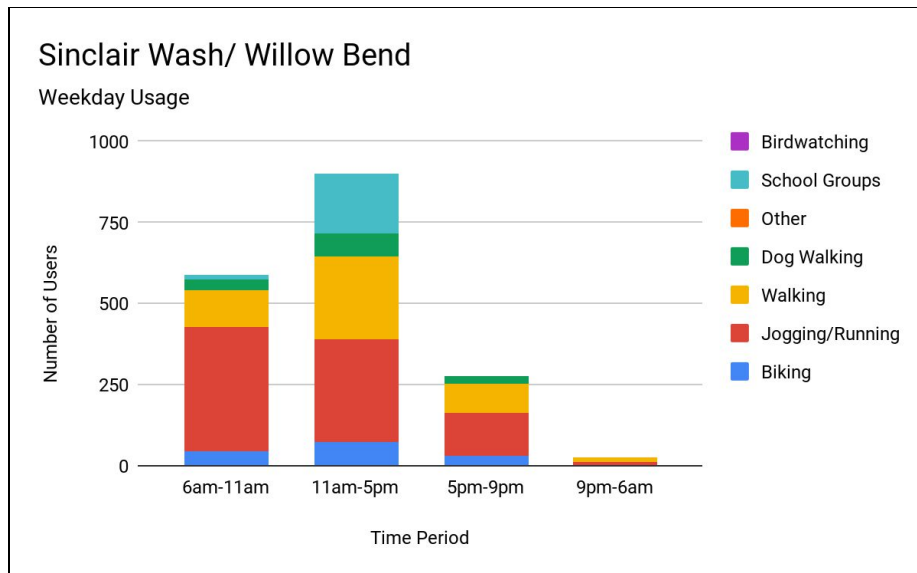


Figure 8: Weekday trail usage from two cameras placed along the FUTS passage stretching from Lone Tree Road past the Willow Bend Education Center.

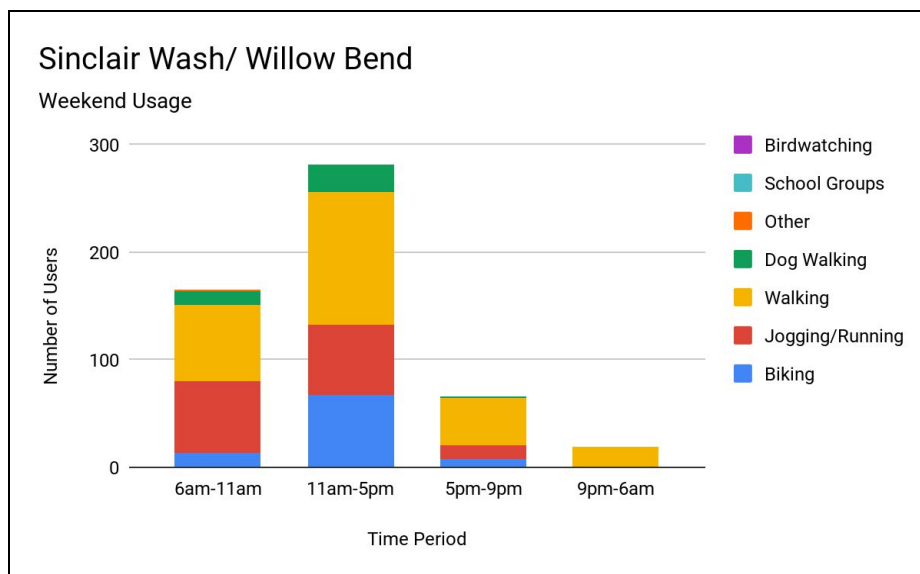


Figure 9: Weekend trail usage from two cameras placed along the FUTS passage stretching from Lone Tree Road past the Willow Bend Education Center.

Wetlands at I-40

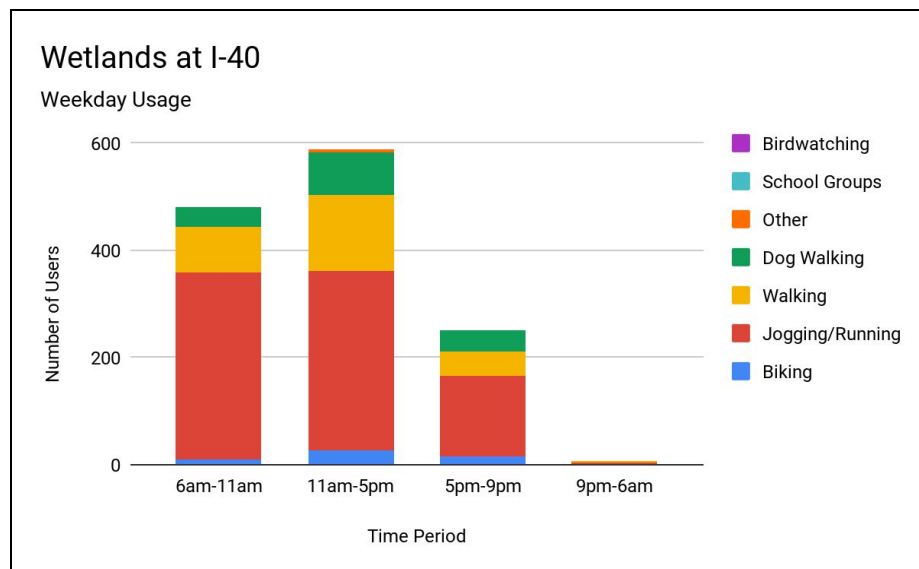


Figure 10: Weekday trail usage from one camera placed on the FUTS passage next to the wetlands located near I-40.

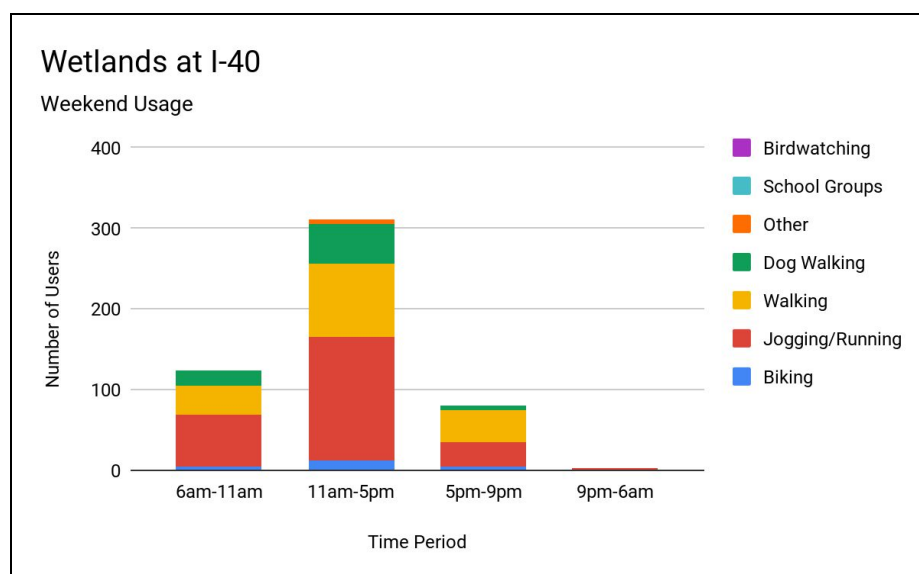


Figure 11: Weekend trail usage from one camera placed on the FUTS passage next to the wetlands located near I-40.

Community Results

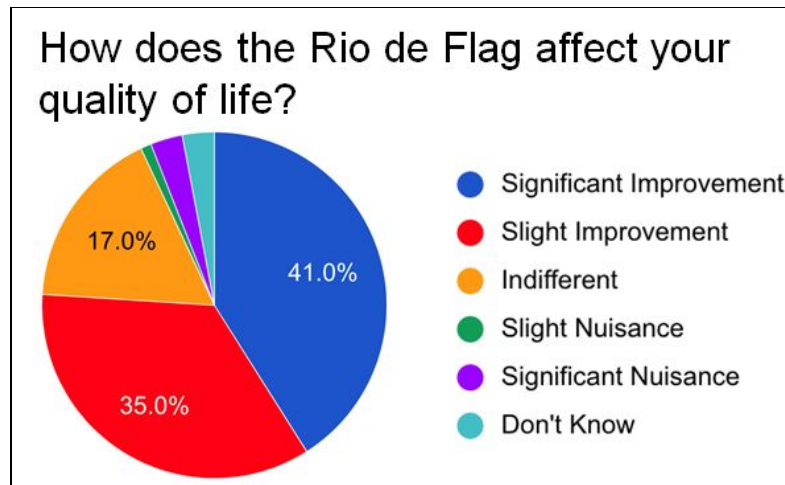


Figure 12: Chart from survey detailing the percentages of the question “How does the Rio de Flag affect your quality of life?” compiled from responses from 105 people. The section “Don’t know” was added due to other included responses.

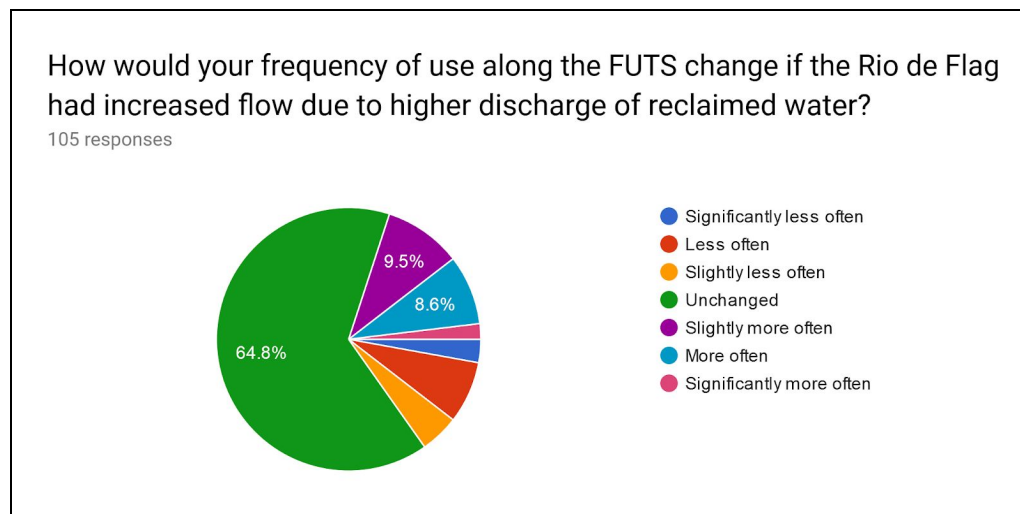


Figure 13: Chart from survey detailing the percentages of the question “How would your frequency of use along the FUTS change if the Rio de Flag had increased flow due to higher discharge of reclaimed water?”

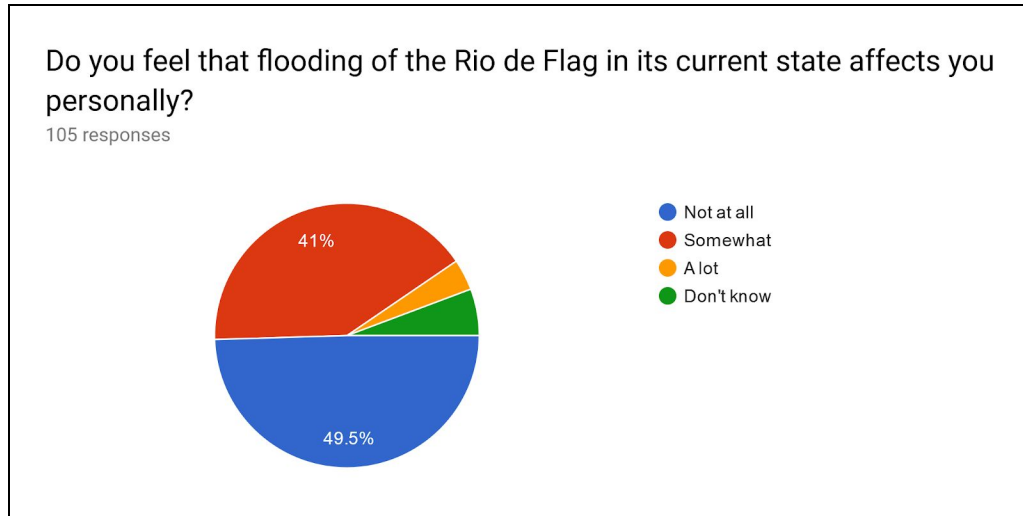


Figure 14: Chart from survey detailing the percentages of the question “Do you feel that flooding of the Rio de Flag in its current state affects you personally?”

All survey responses can be found in the Appendices A-E

All trail usage data can be found in the Appendices F-G

Discussion

Environmental Value

Areas showing significant seepage loss were from Frances Short Pond to City Hall, and Willow Bend to the Wetlands. Areas with a moderately high k_{sat} (ability of water to move through a material) and a high percent of sand were considered excellent soils for aquifer recharge. High clay content, low k_{sat} , and unconsolidated bedrock material were considered poor soils for recharge potential. Seepage results from a 2010 USGS evaluation correlate with soil data very strongly.

The soil seepages along with proposed infrastructure changes demonstrate that recharge to the C aquifer could be very efficient within the City of Flagstaff (Figure 3). The city is attempting to create a closed circuit within city limits. This potentially would guarantee recharge into the C aquifer. Currently water being discharged from the Wildcat Treatment Plant has been verified to be recoverable into the aquifer. However, wells in this area are too far from city limits and cannot be used as a water source within the city. The goal with the infrastructure changes is to increase recharge into the C aquifer by 100%. Discharge of reclaimed water would not necessarily increase overall into the system, however infrastructure changes will allow for more discharge of reclaimed water flowing through town than currently observed. Recharge into the wells closer to city limits provides a reusable water source for the city. Discharge of reclaimed water will still continue to flow at a rate correlated with response to city demands and private stakeholders.

In addition to soil seepage, areas experiencing high erosion, such as Sinclair Wash, would benefit from erosion and flood control as this tends to be an area used frequently for recreation.

The Rio de Flag within the study area has proven to be efficient in its potential for soil recharge. Optimizing on an increase of reclaimed water discharge throughout the study area could provide benefits to future water security.

Health concerns with reclaimed water will need to be evaluated for future use. Effects of compounds of emerging concern were beyond the scope of this study, however their effects will need to be considered by the city in the future. Future flood management planning should prioritize soil recharge with infrastructure changes so that the benefits can be optimized to their full potential.

Recreational Value

A review of the photos from the trail cameras found that sections of the FUTS along the Rio de Flag are valuable to community members. As many as 2093 individual trail users were captured on certain sections. A total of 9014 trail users were recorded over the two week span the cameras were left out. Type of usage varied, with walkers, cyclists, runners, dog walkers, birdwatchers, fishers, and school groups all being recorded. Some more unique trail usages included people on self-balancing scooters, a horse and carriage, and wheelchair users. The plethora of uses found on the FUTS speaks to the importance of these trails and the Rio to all community members. These features of the community are accessible and valuable in ways that other outdoor amenities might not be.

Northern sections of the FUTS were used more heavily by walkers and cyclists than southern sections (Figures 2-5). Although true intention cannot be determined by photographs, it can be reasonably inferred that many of these users are commuting due to the time of day (i.e. weekday mornings and afternoons) and mode of transportation that was recorded. Frances Short

Pond also showed heavier usage by school groups than any other section of the study area (Figure 2). This section of the Rio is easily accessible from multiple different schools, and proves to be a useful educational tool.

Southern sections of the FUTS were more heavily used by joggers and dog walkers (Figures 6-9). It can be reasonably inferred that these trail users are using these sections for recreation as opposed to a form of transportation. Flagstaff has an active outdoor community, and community members value the ability to recreate along stretches of the Rio de Flag.

In planning for the future, it is important to consider the value the community places on being able to commute and recreate along the Rio. In looking at survey results, trail users have indicated a positive association with being able to recreate alongside running water. However, trail users are also concerned about the ways in which flooding may affect their usage. Plans for reclaimed water discharge and flood control should take into account the value of having accessible, usable trails along the Rio de Flag.

Community Value

Overall, there were 105 responses to the FUTS and Rio de Flag Use survey with the majority of people living off of NAU campus and were between the ages of 19 and 35. The biggest use of the FUTS system along the Rio de Flag was found to be for biking and walking with commuting coming in third. This signifies that the quality of the trails are important for bikers and the a huge portion of community value is due to commuting and providing a pathway for people trying to get around town. While almost 2/3rds of people did not feel their usage of the FUTS system would change if the Rio had more water flowing in it, as evident in Figure 13, many people commented that they would be interested in seeing more water for aesthetic value

or potential wildlife value for the area. Others expressed their concern for potentially flooded trails and the quality of the treated reclaimed water that would potentially flow. Some comments related to usage are:

“I cross the rio to get to work. When it floods, I have to drive or ride my bike on the street.”

“I'd be tempted to check out the flows. Floods are fun to watch, and I'd want to see what kind of erosion is happening and what plants may have prevented it along certain stretches.”

“It's nice to walk next to flowing water but I wouldn't seek it out that much more; maybe a bit”

“Because the Rio would be nicer to look at with higher flow, and my dog would like to play in the river”

“Flooding could make it harder for me to travel, therefore I may use an alternative route.”

“I would be scared about coming in contact with wastewater.”

“more consistent water flow would attract more wildlife”

“Having running water in Flagstaff would make the trail more appealing to me, and I would probably walk it and birdwatch on it more than just commute by bike on it.”

“would take more classes for field trips”

Overall, the community seems interested or unbothered by increased flow within the Rio de Flag along the FUTS trail due to diverted treated reclaimed water, based on survey results. As

shown in Figure 12, the majority of responses state that the FUTS trails along the Rio de Flag either has a significant improvement or a slight improvement on their quality of life. If the city were to go forward with a plan to increase discharge of treated reclaimed water into the Rio de Flag or something related, it is important to also consider the communal implications, responses, and possible concerns as well.

Conclusion

Community responses and trail use data provide great insight into trail appreciation. Many users noted that they fear flooding of the FUTS due to their value of commuting and recreation. This is valuable information for areas such as Sinclair Wash, for example. Sinclair Wash and Willow Bend were found to be heavily eroded, and the soil was a clay in the heavily incised locations (Figure 1). A vegetated bank could prove to be a solution to flood control as it would stabilize the banks along the trailside. This area was also observed to be a heavily used location for joggers and walkers (Figures 8 and 9). When evaluating community input on the need for flood control, quantitative data of use type, and environmental factors, it is more likely that flood control in this area would be supported by the city.

Flood control in the Sinclair Wash and Willow Bend area is one example of the potential applications of this research. Community value and environmental functions along the Rio de Flag provide insight into future flood control, erosion control, and water security for the City of Flagstaff. The Rio de Flag and the FUTS improve on users quality of life, provide many different types of recreational and educational values, and have proven to be efficient in soil recharge along its reaches.

Margin of Error

For this project, the greatest margin of error was human error related to trail cameras. Not all six cameras were online for the full two week's time and therefore data does not cover the exact same time frame. Cameras went offline either due to unexpected battery drain due to aging rechargeable batteries or due to its memory card running out of storage space. This could have been avoided somewhat if cameras were checked halfway through the data collection period and memory cards were switched out or batteries were replaced. This may have also been avoided if the cameras were powered by newer batteries.

Weather was not taken into consideration when evaluating results from trail usage. If trail use data were to be recounted, it would be recommended to count for a longer period of time and throughout different seasons. Weather provides more insight into trail usage and is a more realistic view into recreational value.

Another large margin of error with this project was community exposure to the survey. Survey results have a slight bias due to the authors sharing the survey via Facebook and Friends of the Rio sharing the survey to their contacts. Additionally, the survey was only able to be sent to the NAU SES list-serv. This margin of error could have been avoided or improved upon if the survey was created a month sooner which would have allowed for more time to contact someone at NAU to send the survey to the whole campus. This additional time would have also allowed for more time to potentially get the survey approved by the city and sent out that way to the greater Flagstaff area.

Works Cited

Bills, Donald. Rio De Flag Seepage Evaluation. USGS, 2010, Rio De Flag Seepage Evaluation
Nrcs. Web Soil Survey, websoilsurvey.sc.egov.usda.gov
Young, Erin. Recharge Feasibility Study. 18 October 2018

Acknowledgements

Friends of the Rio for guiding trail use research and forwarding out the community survey.

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Donald J Bills for insight on USGS Seepage Study results and on data received from NRCS

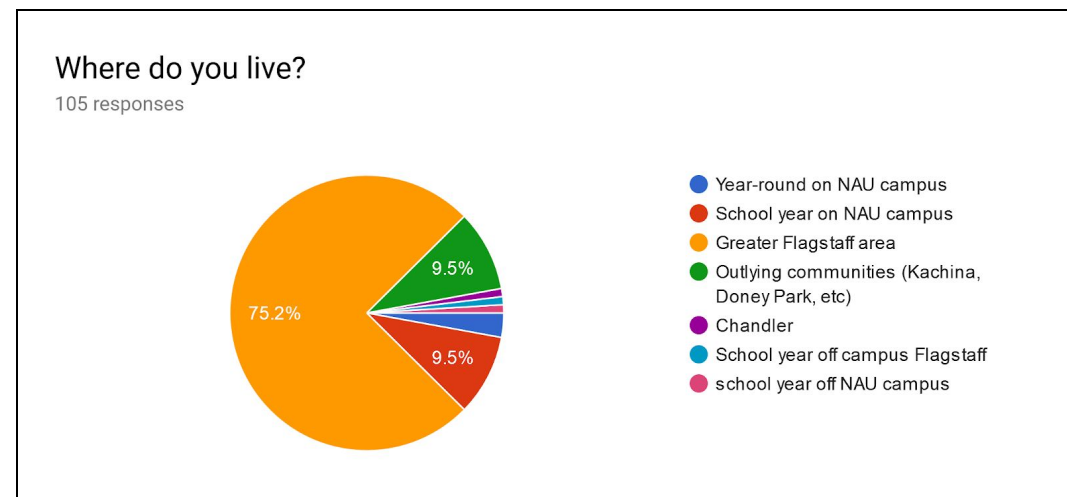
Sarah Colby for forwarding out our survey to the NAU campus.

All participants in the community survey who made data collection on perceived values possible.

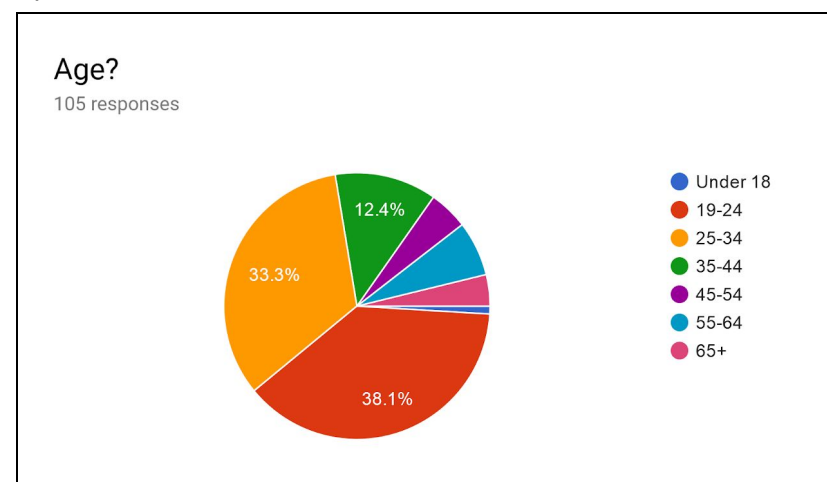
Appendix

Survey Results: A-E

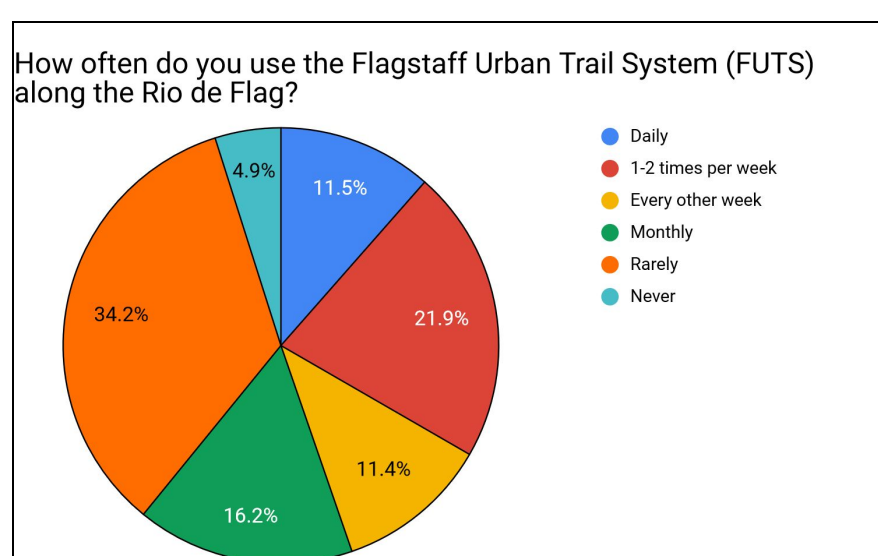
A.

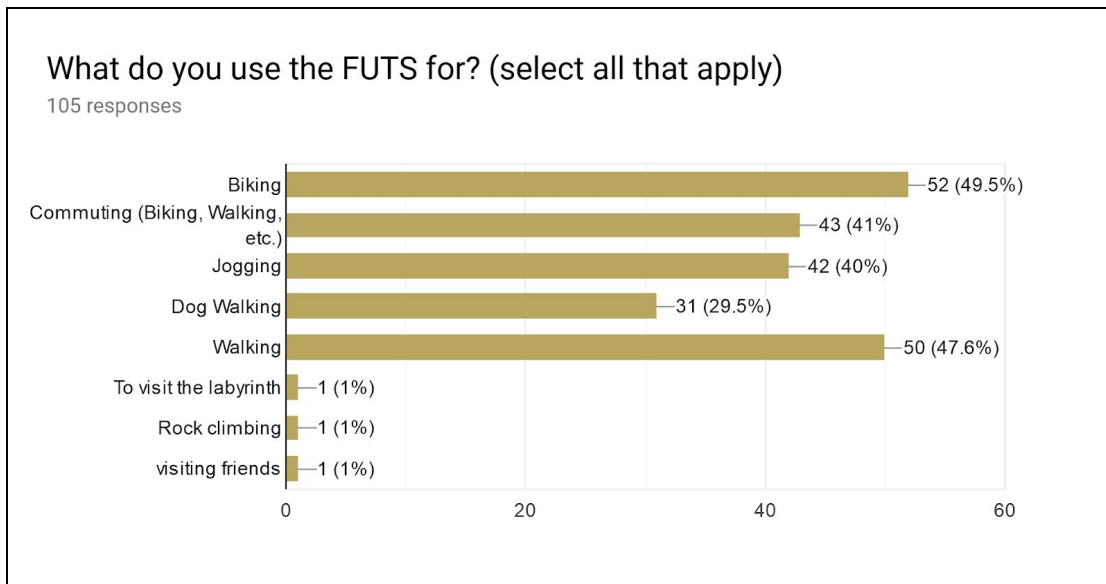
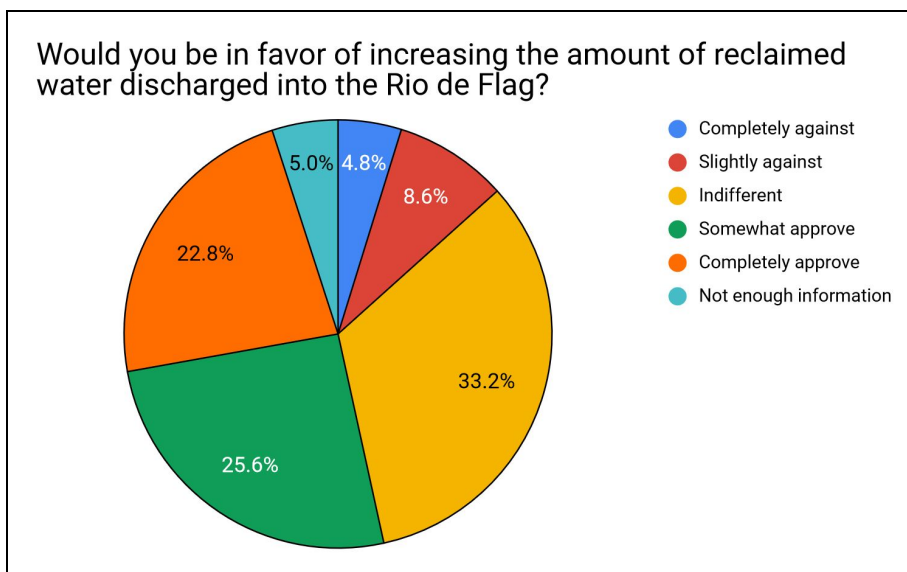


B.



C.



D.**E.**

Trail Usage Data: F-G**F. Weekday trail usage by camera**

Frances North	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	57	93	13	1	164
Jogging/Running	135	159	42	3	339
Walking	125	301	92	13	531
Dog walking	48	80	37	1	166
Other	4	29	3	0	36
School Groups	334	89	0	0	423
Birdwatching	3	4	0	0	7
Total (time)	706	755	187	18	1666

Frances South	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	23	97	26		146
Jogging/Running	83	106	41	4	234
Walking	114	519	77	21	731
Dog walking	91	83	48	5	227
Other	42	7	0	0	49
School Groups	0	221	0	0	221
Birdwatching	2	0	0	0	2
Total (time)	355	1033	192	30	1610

Downtown	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	5	11	0	0	16
Jogging/Running	10	23	8	0	41
Walking	54	257	30	1	342
Dog walking	8	9	7	0	24
Other	0	6	0	0	6
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	77	306	45	1	429

Sinclair Wash	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	41	62	27	1	131
Jogging/Running	293	226	103	8	630
Walking	78	193	61	14	346
Dog walking	21	44	17	1	83
Other	0	0	0	1	1
School Groups	8	154	0	0	162
Birdwatching	0	0	0	0	0
Total (time)	441	679	208	25	1353

Willow Bend	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	5	13	2	0	20
Jogging/Running	87	88	29	1	205
Walking	36	62	30	0	128
Dog walking	13	27	8	0	48
Other	0	0	0	0	0
School Groups	6	29	0	0	35
Birdwatching	0	0	0	0	0
Total (time)	147	219	69	1	436

Wetlands	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	10	26	15	1	52
Jogging/Running	350	335	150	3	838
Walking	85	143	47	2	277
Dog walking	37	80	40	0	157
Other	0	3	0	0	3
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	482	587	252	6	1327

G. Weekend trail usage by camera

Frances North	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	14	28	10	0	52
Jogging/Running	21	26	11	0	58
Walking	37	96	21	2	156
Dog walking	22	40	4	0	66
Other	2	23	2	1	28
School Groups	0	0	0	0	0
Birdwatching	0	4	0	0	4
Total (time)	96	217	48	3	364

Frances South	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	21	66	8	2	97
Jogging/Running	21	24	9	1	55
Walking	52	179	15	9	255
Dog walking	31	36	7	2	76
Other	0	0	0	0	0
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	125	305	39	14	483

Downtown	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	18	19	3	0	40
Jogging/Running	9	18	2	0	29
Walking	46	133	11	0	190
Dog walking	15	18	3	0	36
Other	0	2	0	0	2
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	88	190	19	0	297

Sinclair Wash	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	13	62	8	0	83
Jogging/Running	56	57	13	1	127
Walking	62	100	43	15	220
Dog walking	12	16	2	0	30
Other	1	0	0	0	1
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	144	235	66	16	461

Willow Bend	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	0	5	0	0	5
Jogging/Running	11	8	0	0	19
Walking	9	24	0	3	36
Dog walking	1	9	0	0	10
Other	0	0	0	0	0
School Groups	0	0	0	0	0
Birdwatching	0	0	0	0	0
Total (time)	21	46	0	3	70

Wetlands	6am-11am	11am-5pm	5pm-9pm	9pm-6am	Total (usage)
Biking	4	12	5	1	22
Jogging/Running	65	153	29	2	249
Walking	35	92	40	0	167
Dog walking	19	49	6	0	74
Other	0	5	0	0	5
School Groups	0	0	0	0	0
Birdwatching	1	0	0	0	1
Total (time)	124	311	80	3	518